

REMARKS

This Preliminary Amendment cancels, without prejudice, claims 1-15 in the underlying PCT Application No. PCT/DE03/02089 and adds new claims 16-33. The new claims, *inter alia*, conform the claims to United States Patent and Trademark Office rules and do not add any new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including the Abstract) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(ii) and 1.125(c), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

The underlying PCT Application No. PCT/DE03/02089 includes an International Search Report, dated October 28, 2003, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

It is respectfully submitted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

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METHOD AND CONTROL DEVICE FOR TRIGGERING SOLENOID VALVES
ASSIGNED TO GAS-EXCHANGE VALVES

FIELD OF THE INVENTION

The present invention relates to a method and a device for triggering solenoid valves assigned to gas-exchange valves.

5 BACKGROUND INFORMATION

In the case of internal combustion engines, it is known to replace the conventional valve mechanism having camshafts by an electrohydraulic valve actuation. In such an electrohydraulic valve actuation, the gas-exchange valves are assigned solenoid valves, which control the inflow and outflow of a pressurized fluid – an hydraulic oil – into the working 10 chamber of an hydraulic working cylinder. The position of the corresponding gas-exchange valve is modified via the charge of the working chamber of the hydraulic working cylinder.

The advantage of such an electrohydraulic valve timing is that the individual gas-exchange 15 valves of the internal combustion engines may be actuated independently of each other. This provides great variability of the opening and closing instants of the gas-exchange valves. The variability is given both among the gas-exchange valves of different combustion chambers and also among the gas-exchange valves of an individual combustion chamber. By appropriate coordination of the actuation of the solenoid valves, for instance, the valve actuation of two 20 gas-exchange valves having the same function, i.e., two intake valves or two discharge valves, may be synchronized and any existing component tolerances or system-intrinsic deviations be compensated in synchronism.

It is thus known from electrohydraulic valve actuators to ascertain a trigger signal for each 25 individual solenoid valve in a control device, in time-synchronism with the crankshaft motion and possibly as a function of the driving state of the vehicle, the operating states of the internal combustion engine and also as a function of driver inputs. This signal is transmitted to an output stage via an appropriate trigger line. In response to the actuation signal, the corresponding solenoid valve will then be triggered by means of the output stage.

This assumes that a separate control line between the control device and the output stage is provided for each solenoid valve, which causes high cabling expenditure and requires correspondingly higher computing power in the control device. Each actuating signal of the
5 control device must be ascertained and generated in synchronism with the crankshaft.

SUMMARY

It is the ~~objective~~an object of the present invention to reduce the wiring, computing and control outlay required for the activation of the solenoid valves while retaining an individual activation
10 of the gas-exchange valve with respect to each other.

This ~~objective~~isobject may be achieved by the method and the devices of the present invention.

15 The present invention relates to a method for triggering solenoid valves assigned to gas-exchange valves in an electrohydraulic valve actuation of an internal combustion engine having a plurality of combustion chambers. The solenoid valves assigned to the gas-exchange valves may be activated independently of each other. To this end, crankshaft-synchronous trigger signals for solenoid valves of the internal combustion engine are ascertained in a control
20 unit and transmitted to an output stage. The output stage controls the solenoid valves on the basis of the transmitted trigger signals. Each combustion chamber of the internal combustion engine has at least one intake valve and at least one discharge valve as gas-exchange valve.
According to the present invention, all solenoid valves of all gas-exchange valves of a combustion chamber form a solenoid valve set. In each case, an activation profile is specified
25 for all solenoid valves of a solenoid valve set. A crankshaft-synchronous activation signal is ascertained for each combustion chamber in the control unit and supplied to the output stage. The output stage controls the solenoid valves of the solenoid valve set based on the activation signal of the cylinders in accordance with the activation profile stored for the individual solenoid valve.

30 This procedure is based on the fact that while considerable differences may exist between the solenoid valves of different gas-exchange valves of a combustion chamber, the activation of all solenoid valves nevertheless follows a basic pattern, no great variance existing among equivalent solenoid valves of different combustion chambers. For that reason, an activation

- profile for each solenoid valve of a solenoid valve set is first generated in the control unit. This determination and the transmission of this information does have to be implemented rapidly, but not in synchronism with the crankshaft. The triggering of the individual solenoid valves and their synchronization with respect to the crankshaft is implemented via the activation
- 5 signal assigned to the corresponding combustion chamber. This ensures a combustion-chamber-individual synchronization, while the profile of the solenoid-valve activations of equivalent solenoid valves of the different combustion chambers corresponds to each other.
- 10 Due to the constant recalculation of the activation profiles for the solenoid valve set, the activation instants of the solenoids valves are able to be continuously adapted to the instantaneous driving state, and the driving wish of the driver may be implemented. In general, the variability and adaptability of the activation instants and activation durations of the gas-exchange valves of the internal combustion engine are maintained. Nevertheless, a
- 15 synchronization of the recalculation with respect to the crankshaft is no longer required. The triggering may be implemented not only in synchronism with the crankshaft, but simultaneously in a time-synchronous manner as well.
- According to an advantageous development of the present invention, it is provided that a
- 20 specific activation profile may be ascertained for each individual solenoid valve of the solenoid valve set. In this way, the activation of the solenoid valves is largely adapted to the driving state.
- According to an advantageous development of the present invention, the activation signal for
- 25 each individual cylinder is may be a binary signal, is may be ascertained in the control device, and may be transmitted to the output stage. The binary signal is an easily generated signal whose information content is sufficiently high. Furthermore, it is may be advantageous if the activation signal for each individual cylinder is transmitted to the output stage on a cylinder-specific activation-signal line. In this way, a mutual decoupling of the activation
- 30 signals of the various activation signals is achieved in a simple manner.

According to an advantageous development of the present invention, the output stage activates may activate the solenoid valves of a cylinder on the basis of the value change of the activation signal of this cylinder in accordance with the corresponding activation profile. In

particular in connection with a binary signal, a change from the first to the second value of the activation signal may have a different function than a change from the second to the first value of the activation signal. According to a preferred development, the activation of solenoid valves assigned to the intake valves is carried out on the basis of a first value change between two values of the activation signal, and the activation of solenoid valves assigned to the discharge valves is carried out on the basis of a second value change between two values of the activation signal, the second value change differing from the first.

According to a preferred development of the present invention, activation profiles ~~are~~may be determined in the control device and transmitted via a data line to the output stage, where they are stored in a memory unit for use in the triggering of the solenoid valves. In the process, the activation profiles stored in the memory unit of the output stage are updated during the operation of the output stage, to values preferably newly ascertained in the control device.

According to an advantageous development of the present invention, an activation profile is made up of a rectangular profile, which defines the onset and the duration of the activation of the solenoid valve with respect to the instant established by the corresponding activation signal. According to a preferred development of the present invention, an activation profile ~~is~~may be made up of the specification of four consecutively occurring time durations. The first time duration represents the length of a waiting time; the second time duration defines the duration of an application of a pull-up voltage at the solenoid valve; the third time duration determines the length of a free-flight phase, and the fourth duration is the duration of an application of a holding voltage at a solenoid valve.

According to a preferred development of the present invention, an adaptation set ~~is~~may be determined in the control device, the adaptation set including a solenoid-valve-specific adaptation of the values of the activation profile for solenoid valves of a solenoid valve set. The values of the adaptation set are transmitted from the control device to the output stage, in particular by means of a second data line, which is separate from the first data line. For each solenoid valve set, one adaptation group of adaptation sets is preferably determined for all solenoid valves of the solenoid valve group. This measure allows an individual solenoid valve activation of each solenoid valve. Different activation times with respect to the individual activation signal may also be achieved between equivalent solenoid valves of different solenoid valve sets. As a result, the individual solenoid valves remain independent of one

another. This development of the present invention thus combines the advantage of reduced computing and control-line outlay and the advantages of an independent valve actuation. This may be utilized in particular due to the fact that the temporal change in the characteristic of equivalent solenoid valves of different solenoid valve groups with respect to each other occurs
5 relatively slowly, for instance as a result of deviating temperature developments among the solenoid coils of the solenoid valves, whereas the change in the activation profiles of the solenoid valve sets occurs more often and more rapidly due to the driving condition.

The subject matter of the present invention ~~is also~~ includes a circuit arrangement for triggering
10 solenoid valves assigned to gas-exchange valves. Trigger signals for the activation of the solenoid valves are determined in a control unit. The control unit transmits signals to an output stage via corresponding lines. The output stage triggers the solenoid valves. According to the present invention, the lines between the control unit and the output stage are data lines for the transmission of activation profiles of solenoid valves and activation-signal lines for the
15 crankshaft-synchronous activation of the actuation of the solenoid valves of cylinders in response to activation signals.

According to the present invention, the required cabling between control unit and output stage
~~is~~may be considerably reduced due to the provision of the activation-signal lines and the one
20 data line. The number of lines is reduced because the output stage is able to trigger a multitude of solenoid valves via the signal from an activation-signal line since the solenoid valves have been combined into solenoid valve groups.

According to an advantageous development, an activation-signal line between control unit and
25 output stage ~~is~~may be provided for each cylinder. According to an advantageous development of a circuit arrangement according to the present invention, a second data line is provided to transmit the adaptation sets. Furthermore, it ~~is~~may also be advantageous if the output stage includes a memory unit for storing at least the actuation profiles of the solenoid valve sets.

30 In addition, ~~it corresponds to~~in one advantageous ~~development~~development of the present invention ~~if~~, a processing unit is provided in the output stage to ascertain the trigger signals from the activation profiles and the activation signals and possibly from the adaptation sets.

BRIEF DESCRIPTION OF THE DRAWINGS

Furthermore, the present invention is also elucidated explained in greater detail in the with reference to an exemplary embodiment shown in the drawing. The figures show:

Figure 1 shows a schematic representation of an example circuit configuration according to 5 the present invention;

Figure 2 shows the flow chart of an example method according to the present invention; and

Figure 3 shows the time characteristic of activation profile and trigger signal.

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DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

Figure 1 shows an example circuit arrangement 10 according to the present invention in a schematic representation. The circuit arrangement has a control device 11 in which the activation profiles and the adaptation sets are ascertained. The control device is connected to 15 output stage 18 via a plurality of lines 12, 13, 14. First data line 12 is used to transmit the activation profiles; second data line 13 transmits the adaptation sets. A memory 17 in which a first memory 15 is provided to store the activation profiles and a second memory 17 to store the adaptation sets, is available in output stage 18. In addition, activation-signal lines 12 are formed between control device 11 and output stage 18. One activation-signal line 12 is 20 provided for each solenoid valve set MG1, MG2, MG3.

A processing unit 19 in output stage 18 ascertains the trigger signals from the activation profiles stored in memory 17 and the adaptation sets. The activation signals transmitted via activation-signal lines 12 energizes trigger lines 20, which in each case lead to a specific 25 solenoid valve M1, ..., M5 of one of solenoid valve sets MG 1, ..., MG3. Same-numbered solenoid valves Mi of solenoid valve sets MG 1, ..., MG3 are solenoid valves that correspond to one another, which are triggerable by the same activation profile, possibly with the exception of an adaptation based on an adaptation set.

30 Solenoid valves M1, ... M5 in each case form a solenoid valve set MG1, ..., MG3. For the purpose of simplification, three solenoid valve sets having five solenoid valves Mi, i=1, ..., 5 in each case are shown in Figure 1. However, the number of solenoid valves Mi in a solenoid valve set is also adaptable according to the specific circumstances, as is the number of solenoid valve sets.

Figure 2 shows the flow diagram of aan example method according to the present invention in a schematic depiction. Steps 110, 111; 120, 121; 130, 131 are executed in the control unit and may by all means be carried out in parallel to one another. Steps 140 and 141 are executed in
5 the output stage and are performed in parallel with the execution of the method steps performed in the control unit.

According to step 110, activation profiles 24a, 24b (Figure 3) are ascertained and subsequently transmitted to output stage 18 via first data line 13 according to step 111. According to step 120,
10 the adaptation sets are ascertained and transmitted to output stage 18 via second data line 14 according to step 121. According to step 130, activation signals 23 are determined in synchronism with the crankshaft rotation. According to step 131, they are then transmitted to output stage 18 via activation-signal lines 12.

15 According to step 140, the values required to trigger solenoid valve M_i are then determined in output stage 18 on the basis of the available values of the adaptation sets and the activation profiles for a specific solenoid valve M_i ($i=1, \dots, 5$) of a solenoid valve set MG_j ($j=1, \dots, 3$). If an activation profile 24 for mutually corresponding solenoid valves M_i of solenoid valve sets MG_1, \dots, MG_3 is specified by the four numerical values $T_{i1}, T_{i2}, T_{i3}, T_{i4}$ (cf. Figure 3), and
20 an adaptation set for solenoid valve M_i of solenoid valve set MG_j by the four values $A_{ij1}, A_{ij2}, A_{ij3}, A_{ij4}$, a data set $D(M_i, MG_j)$ that characterizes the triggering according to the equation $D(M_i, MG_j) = (T_{i1} * A_{ij1}, T_{i2} * A_{ij2}, T_{i3} * A_{ij3}, T_{i4} * A_{ij4})$ will result for this solenoid valve. The values A_{ijn} with $n=1, \dots, 4$ of an adaptation set are thus scaling factors. According to step 141, solenoid valves M_i of solenoid valve groups MG_1, \dots, MG_3 are activated
25 according to the arrival of activation signals 23. As an alternative to scaling using factors as it is shown here, the adaptation set may also include correction values directly, which are then linked to the solenoid valve set by addition.

30 Figure 3 shows the time characteristic of an activation signal 23 and, in parallel thereto, the characteristic of two activation profiles 24a, 24b. Activation profiles 24a, 24b are assigned to one solenoid valve M_i in each case. Solenoid valve M_i having activation profile 24a is assigned to an intake valve of the internal combustion engine, while solenoid valve M_i having activation profile 24b is assigned to a discharge valve of the internal combustion engine, both solenoid valves being associated with a solenoid-valve set MG_j . Activation signal 23 changes its value

in a crankshaft-synchronous manner at the instant of ascending edge slope 21, for instance from 0 to 1. Activation profiles 24a of solenoid valves Mi assigned to the intake valves are established according to this instant. The activation signal has a predefined duration and then changes its value again. This is represented by trailing edge 22. Activation profiles 24b of
5 solenoid valves Mi assigned to the discharge valves are calculated according to this instant.

Each activation profile of a solenoid valve Mi is made up of four consecutive time segments, Ti1, Ti2, Ti3, Ti4. Waiting time Ti1 indicates what time the activation of solenoid valve Mi begins after the particular edge. For the pull-up voltage duration Ti2, solenoid valve Mi has a
10 pull-up current applied. This is followed by a free-flight phase having duration Ti3 during which the solenoid valve is not energized. Next comes holding time Ti4 during which the solenoid valve is energized by a holding current.

Due to adaptation sets Aij, activation profiles 24a, 24b are able to be adapted to the individual
15 conditions of a solenoid valve Mi of solenoid-valve set MGj. Adaptation sets Aij of all solenoid valves Mi, i=1, ..., 5 of a solenoid-valve set form an adaptation group.

SummaryABSTRACT

The present invention relates to a method for triggering solenoid valves assigned to gas-exchange valves in an electrohydraulic valve activation of an internal combustion engine having a plurality of combustion chambers. The solenoid valves assigned to the gas-exchange valves may be activated independently of each other. To this end, crankshaft-synchronous trigger signal for solenoid valves of the internal combustion engine are ascertained in a control unit and transmitted to an output stage. The output stage controls the solenoid valves on the basis of the transmitted trigger signals. Each combustion chamber of the internal combustion engine has at least one intake valve and at least one discharge valve as gas-exchange valve.

According to the present invention, all solenoid valves of all gas-exchange valves of a combustion chamber form a solenoid-valve set. One activation profile in each case is specified for all solenoid valves of a solenoid valve set. In the control unit, a crankshaft-synchronous activation signal is ascertained for each combustion chamber and supplied to the output stage.

The output stage triggers the solenoid valves of the solenoid-valve set on the basis of the activation signal of the cylinders according to the activation profile stored for the individual solenoid valve.

(Figure 1)